

# EXPERIMENTAL MUSICAL INSTRUMENTS

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FOR THE DESIGN, CONSTRUCTION AND ENJOYMENT OF UNUSUAL SOUND SOURCES

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## STRINGS, BALLOONS, WINDWANDS

Hello, everyone.

Three main articles appear in this issue. "Musical Strings" is the first half of a two part look at basics of string behavior, and the diverse materials, both familiar and exotic, that can function as strings. "Spirit Catchers and Windwands" is the third and final installment in EMI's series on spun or swung instruments, this time featuring wind-sounded bamboo structures made by Darrell De Vore. Thirdly we have the article that follows here on this page, and since we're very tight for space in this issue (as usual), let's just jump right in to that one now.

describing actual and possible applications, and hope it all adds up to something in the end.

## BAGPIPES AND BLADDER PIPES

The most common use for inflated animal bladders in musical instruments has been as air reservoirs for bagpipes. Bagpipes are ancient instruments, now found in various forms throughout Eastern and Western Europe and to a lesser extent in other parts of the world. No need to describe them in detail here, except to review basic construction

(continued on page 16)

## BALLOONS & BLADDERS

By Bart Hopkin

This article meanders through several dominions. Its two subjects, balloons and bladders, have much common ground but part ways in some of their potential musical uses.

"Bladder" here refers to any inflatable membrane. Inflated membranes can be made of many different materials, the most common historically perhaps being animal bladder. They have been important, in diverse capacities, to a variety of musical instruments.

"Balloons" refers to the familiar children's party toy. In their intended form, they too are inflated membranes. But in talking about balloons we'll also wander in other directions, and look at some of the unexpected musical things that can be done with balloon rubber and similar stretchy membranes in uninflated, un-bladder-like forms.

Can I start with some general ideas that will provide us a handle on the subject matter? I don't really see how -- the musical potentials of the materials are too divergent for effective generalization. Instead I will simply begin

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I READ WITH GREAT INTEREST Hugh Davies' article on sampling (in EMI Vol. V #2) but was a bit dismayed to find no mention of Hugh LeCaine's work with tape-recorder sampling starting in the early 1950s. LeCaine was a Canadian scientist, musician and composer whose work was the founding basis for much of the electroacoustic and electronic work in Canada. Folkways released an album of his work in 1967 (which I do not have), but a new record was released more recently (which I have recently found). I have made a copy of the liner notes of the latter for your reading pleasure and enlightenment.

Colin Hinz

From the editor: The more recent recording of LeCaine's work that Colin refers to is **Hugh LeCaine, Pioneer in Electronic Music Instrument Design/Compositions and Demonstrations 1948-1972**, released in 1985 by JWD Music, 146 Ridge Rd. West, Grimsby, Ontario L3M 4E7, Canada. For more on LeCaine's tape work, see also "When the Form has a Sound of Its Own," originally written by LeCaine in 1957 and reprinted in **Musicworks 43**, Spring 1989 (1087 Queen St. West, Toronto, Canada M6J 1H3).

I HEARD MY FIRST BLOWN IDIOPHONE recently; a canoe rack on top of a moving car (without the canoe) will sing a series of eerie pure tones, changing pitch as the car speeds up. At first I thought the square metal bars were simply acting as aerophones, but I discovered that the notes were not a harmonic series, and that touching the bar would dampen the sound.

Clem Fortuna  
516 Hawthorne  
Royal Oak, MI 48067

PS -- This is sort of out of EMI's realm, but I'm keyboard shopping and I have to ask: is there a device available which can give microtonal control over any MIDI instrument? I've heard of such a device but it keeps eluding me. Does it exist?

From the editor: Check EMI's notices section for software capable of microtonal pitch control for specific MIDI controllable instruments. As to whether generalized systems exist that will work for any MIDI instruments -- perhaps some readers will have answers.

## REGARDING "WHIRLED MUSIC"/BULLROARERS/WORLD MUSIC

Each issue of EMI characteristically sets my thoughts a-whirling. I was delighted to discover in Volume V #2 that "EMI T-shirts have never been made and are not for sale;" and I was thoroughly entertained, once again, by the breadth and depth of coverage encountered in 24 pages.

The emphasis on performance activity which David Toop and Max Eastley developed in their explorations of "whirled music" -- "the act of whirling, with its physicality and potential danger and its abrupt dynamic contrasts, was appealing.... When objects are whirled at speed there is a feeling of excitement and threat" -- reminded me of a comment by John Cage: "What is the nature of an experimental action? It is simply an action the outcome of which is not foreseen. It is therefore very useful if one has decided that sounds are to come into their own, rather than being exploited to express sentiments or ideas of order" (Cage 1961:69).

Cage studied music, and played bridge, for a while with the American composer Henry Cowell (1897-1965) of whose influence on experimental music Cage has noted: "Henry Cowell was for many years the open sesame for new music in America" (1961:71). "... I enjoyed [Cowell] ..., together with his interest in music of other cultures. What is now called 'world music' in the universities. He was, I would say, the instigator of

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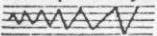
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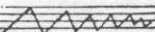
## Ensemble

by Henry Cowell

interest in music of other cultures....Two of the inspiring books -- inspiring because they gave me the permission to enter the field of music -- were **New Musical Resources** by Henry Cowell and **Toward a New Music** by Carlos Chavez" (Cage, in Kostelanetz and Cage 1987:7,39).

In 1925 Cowell published (NY: Breitkopf) a work in four movements called "Ensemble, String Quintet with Thunder Sticks," scored for two violins, viola, two cellos and three thundersticks -- the last being the archetypal whirllophones "commonly but not accurately" (Sachs) named **bullroarers**. A note inside the title page explains:

The Thunder Stick, an instrument used in initiation ceremonies by nearly all tribes of Southwestern American Indians, is a ruler-like board of certain size and weight, which is swung around the head by means of a double-string from which it is suspended. The string should be twisted in advance in order to insure the immediate sounding of the stick. When the stick is swung slowly, a soft whirring is produced; as the speed is increased, a crescendo is obtained, which is accompanied by a rising in pitch. Such a crescendo is notated as follows: 

A diminuendo is notated thus: 

An inevitable moment of silence occurs when the twists of the string reverse. These moments are taken into account in scoring for this instrument.

The scoring of the Thunder Sticks is indicated in the first pages of "Ensemble" after which it is left to the discretion of the performer to improvise.

#### For Thunder Sticks inquire at publishers

Cowell scored a revised version, "Ensemble for String Orchestra," in 1956 (published NY: Associated Music Publishers, 1961), which eliminated the Thunder Sticks. Perhaps "publishers" had not supplied the requisite double string instruments. I have not been able to locate even a single recording of either version of "Ensemble."

#### History

About a century ago "bullroarer" was quite an uncommon term, used only in the Irish counties of Cork and Antrim according to Haddon (1898). However, to European scholars who were interested in world-wide comparative studies and human evolutionary history -- in anthropology, folklore, literature, religion, psychology and musicology (including organology) -- the term **bullroarer** readily named and the instrument came to symbolize the **arche** (floor, threshold, beginnings, origins, first principles) of the human cognitive and historical abyss. "By the end of the nineteenth century, the bullroarer ... had become one of the most controversial and frequently discussed subjects in anthropology, engaging the studious attention of some of the truly distinguished anthropologists of that era (e.g., Frazer, van Gennep, Haddon, Lang, Marett, Pettazoni, Schmidt)" (Dundes 1976:220). "The bull-roarer has, of all toys, the widest diffusion, and the most extraordinary history. To study the bull-roarer is to take a lesson in folklore.... The bullroarer is a very simple invention" (Lang 1884:31,43). "This insignificant toy is perhaps the most ancient, widely-spread, and sacred religious symbol in the world" (Haddon 1898:327). We



ABOVE: The opening bars of Breitkopf's edition of Henry Cowell's **Ensemble**. AT LEFT: Notes from the title page.

live in a different era, one where "bullroarers" and kindred sonic resources are an experimental apex of musical and global consciousness.

#### On Affect

The ancient Greek "bullroarer," called **rombos** or **rhymbos** (see current French **rhombe** and Italian **rombo sonoro**) was mentioned by the 5th century BC playwright Euripides as part of the ritual paraphernalia used by the devotees of Dionysis. Celebrants of those ceremonies practiced possession trance associated with musical performance. "Among the numerous epithets of Dionysis, we find **Bromius**, the 'Roarer,' for he was the 'bull-god, lion-god, earthquake-god' [Dodds 1960:70]" (Rouget 1985:207). However, the musical instrument then considered most closely related to trance states was the **aulos**. Moreover, as surveyed world-wide, any musical instrument carries such a potential; "... among all the instruments used for possession not one stands out as a rule. Practically speaking, they can all do the job; at least, this is what the facts indicate. One may wonder if some particular instrument, by virtue of its specific sound -- violent, strident, piercing, screeching, enveloping, haunting, percussive, who knows? -- might perhaps have turned out to be more capable than any other of contributing physically, in one way or another, to the preparation for and triggering of trance. Clearly this is not the case at all" (Rouget 1985:77-78).

Plato's Pythagorean friend, Archytas, also referred to the Dionysian ritual uses of the **rombos** in the early 4th century BC, but he cites it, along with other instruments, for the purpose of demonstrating relationships between speed of motion, vibration, and variation of pitch and intensity, that is, 'tuning effects:' "... and the same [phenomenon] happens with the **romboi** which are moved [whirled] in the ceremonies; and when they are whirled quietly they produce a low tone, and when vigorously [quickly] a high sound" (Archytas, **Fragment I**, trans. Michaelides 1978:293).

"The terrifying sound of the bull-roarer is made with the clear intention of affecting. It is the transmutation of a material [from discrete insensate physicality to sensate life (p.xx)]; it is not the sound of the paddle roaring through the air which one hears, but the veritable voice of a



FOLLOWUPS AND  
NOTES FROM RECENT CORRESPONDENCE

## Food for Thought/Sweet Sounds

"The people beat the **!goin!goin** [a bullroarer of the **!Kung San**] in order that the bees may become abundant for the people, in order that the bees may go into other people's places, that the people may eat honey. Therefore, the people beat the **!goin!goin** when they desire that the people's bees may go into other people's places, that they may put honey away into bags" (W.H.I. Bleek and L. Loyd, **Bushman Folk-lore**, London, 1911; cited in Kirby 1965:71).

Whirled music is more than "bullroarers," and perhaps could even include a clockwork culinary carousel: "The most singular spit in the world is that of the Count de Castel Maria, one of the most opulent lords of Treviso. This spit turns one hundred and thirty different roasts at once, and plays twenty-four tunes, and whatever it plays corresponds to a different degree of cooking which is perfectly understood by the cook. Thus, a leg of mutton a l'Anglaise will be juicy at the eighteenth [tune], and so on. It would be difficult perhaps to carry further the love of music and gormandizing" (Hone:1830:n.p.). Well, music and food, honey and "bullroarers," have come round again, whether furthered or no, in Claude Levi-Strauss's tetralogy **Mythologiques** (Introduction to a Science of Mythology) where "the world of mythology is round." His discussion of "bullroarers" in Volume II, **From Honey to Ashes** is sandwiched between Volume I, **The Raw and the Cooked**, and Volume III, **The Origin of Table Manners**. Volume IV is **The Naked Man**.

Charles Adams

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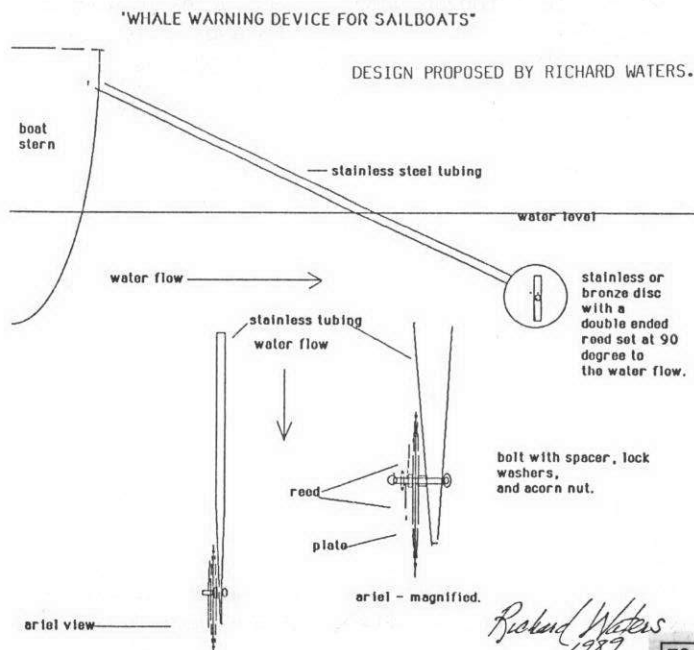
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LAST APRIL A LETTER APPEARED in this space on the subject of whale warning devices. Sail boats sometimes actually strike whales in the water, and the letter writer, Richard Waters, was asking whether anyone had suggestions for, or was interested in trying their hand at designing, an underwater sound-making device to make whales aware of a boat's approach. Since that letter appeared, three basic design types have been suggested. One is a narrow metal reed of some sort, dragged in the water and creating turbulence as the boat moves. Whether this has been tested and found to produce strong enough turbulence at frequencies to which whales will respond, I don't know. Another suggestion has been some sort of percussion system. The percussion, perhaps activated by a small and simple water wheel, could take place above the water line end-on against a rigid rod, and the vibrations be conducted through it to a radiator disk below. The third approach is simply to use an electric underwater speaker system.

After looking over some of these possibilities, Dick Newick (one of those who has been seeking a solution to the problem) had these comments:

"... I have four concerns: What will (1) warn or repel whales, and not attract them; (2) give minimum drag; (3) be a good combination of cheap, easily serviced, and durable; and (4) not so noisy to the crew's hearing that they would decide to take their chances of hitting a whale rather than listen to the damn thing. Almost surely any such device will have to be well aft on the boat to avoid setting up turbulent flow along the length of the hull and to be less vulnerable to being struck by floating objects."

In light of these remarks, percussion systems appear likely to be too cumbersome and too loud aboveboard. The turbulence generating reed looks more promising, if it can be made to perform as





advertised. Electronic systems remain a practical but in some ways less appealing option.

Meanwhile, the matter remains open, as regards both the design of the device and what sorts of sounds will have the desired repelling effect. Richard Waters asks "Does anyone out there in EMI land have anything or anybody that can be added to these ideas? If so, please write EMI or myself so we can help stop these terrible collisions between sailboats and whales." Richard can be reached at 1462 Darby Rd., Sebastopol, CA 95472.

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MORE WHIRLED -- the **Wind Gamelan**: Bill & Mary Buchen recently sent along a copy of a photograph with this descriptive note: "Here is a 'whirled instrument' we built based on Indonesian prototypes. **Wind Gamelan** covers a 4 acre site and will next be installed July-October at Santa Barbara. Seven towers with mirrored propellers reflect a spinning landscape as transparent wind vanes cast moving pink shadows on the ground. Conducted by the wind, each tower plays one note of a scale, creating a music of ringing pointilistic harmonics and ever-changing sequences."

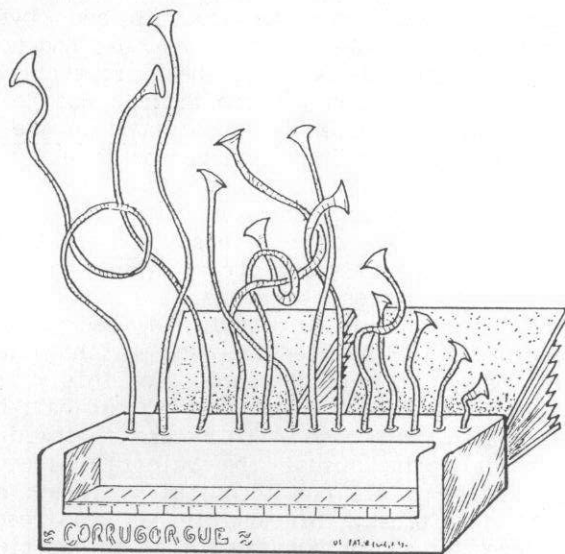
The photo (not reproducible here, unfortunately) shows a set of large scale windmill-like structures in an open field. It appears (Bill and Mary, please pardon me if I'm wrong) that they sound when the rotating of the propellers causes a beater to strike a separately-mounted tuned bar. Each tower has a tail-fin in the form of a triangular frame holding the translucent material mentioned above, which, weathervane-like, pivots the propeller structure under wind power to orient it into the wind.

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BELOW: Dual corrugahorns made by Richard Waters.  
DRAWING AT RIGHT ABOVE: The famous Corrugorgue.

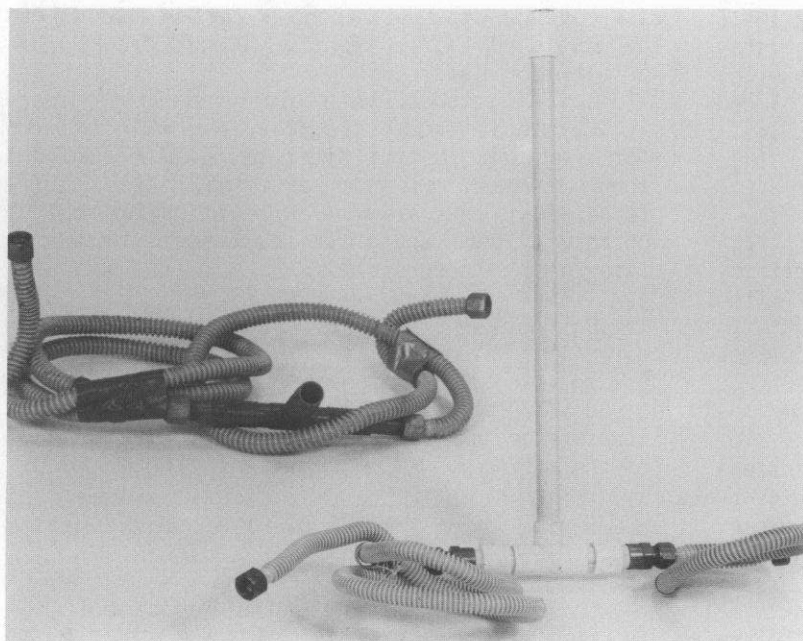
FOLLOWING EMI's last issue's article on Corrugahorns by Frank Crawford, we present here a photo (bottom left) of similar instruments made by Richard Waters. In the Waters instruments the mouthpiece leads to two separate sections of corrugated pipe of differing lengths. The player selects which pipe will sound by covering or not covering the open ends with thumb or fingers to stop the air flow. The pipes operate by the same principles as those described for corrugated pipes in general in Frank Crawford's article.

In response to same corrugahorn piece, Janet Gillies (who proofreads for EMI) says "Why not make a corrugahorn organ?"



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## MUSICAL STRINGS, Part 1

By Bart Hopkin

For quite some time there has been talk about running a good, comprehensive article in **Experimental Musical Instruments** on the many and various types of musical strings: What different materials can be and have been used for strings? How are different string types made? What, on a purely practical level, are the acoustic and physical properties that make for good strings, and how do different materials manifest these properties?

The original plan for the article was to find someone with an extensive background in the subject area, and convince that person to author it. Despite some early leads and false starts, this never came to pass. And so we come to Plan 2. I, your editor, have done my best to pull together information on different string types from a wide variety of sources, organize it and present it here under my own authorship. My background in these areas is not extensive, and so I have leaned very heavily on outside sources for this writing. To ensure that we are not dishing out half-baked information, EMI has in this case followed more stringently than usual the referral procedures that apply to all our technical articles: prior to going to press, this article has been read and corrected by a generous handful of authorities in its various subject areas.

The article will appear in two installments. This first half discusses string vibrating behavior and basic elements of string design, without much reference to specific stringing materials. We will be talking in general principles more than mathematical formulae; still, some of it is admittedly the sort of material that may make liberal arts people's eyes glaze over. The second part, which will appear in the next issue, will look at the diverse sorts of stringing materials and their applications, including common and uncommon materials, natural and synthetic, western and exotic, sensible and silly -- presumably with an enhanced understanding gained from Part 1.

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Strings are the heart of any stringed instrument. That seems obvious. Yet builders, performers and researchers in string instruments often pay surprisingly little attention to strings in themselves. A classic example of this curious disinterest involves replica instruments. For several decades now, people interested in the reproduction of early European instruments for contemporary performance have nurtured a painstaking concern for accuracy in reproducing every detail of the body of original period instruments. Yet it is only relatively recently that that concern has extended to historical correctness in the strings used. When strings believed to be closer in makeup to the originals belatedly became

available and were put in place on some such instruments, people were sometimes surprised by what they heard. Many replicas, in a field where fidelity to the earlier instruments had become an obsession, had apparently all along been sounding quite unlike the originals for which composers of the period wrote -- and all because of insufficient attention to the most basic element!

A similar attitude manifests itself in the world of contemporary western instruments, experimental as well as standard. Makers and players of string instruments tend to give little thought to the wide range of possible approaches to stringing material, instead accepting as given a couple of readily available string types -- usually nylon or spring steel wire, and overwound versions of these.

There are good and simple reasons why this mindset prevails. Among them are the obvious practical considerations of convenience, cost, durability and availability. Another reason has to do with the value of cumulative human experience: these standard materials have been found to be effective; why reinvent the wheel? Still, it is a fact that different string materials really do sound different, as the story of the mis-strung replica instruments illustrates. And even if a string instrument maker or player has no interest in seeking other possible timbres, it's worthwhile at least to understand the basics of the basic material, and to appreciate how and why we got to where we are.

### BASICS OF VIBRATING STRING BEHAVIOR

A common sense definition of a musical string might go something like this: a musical string is a long, thin strand of material which is stretched taut between two fixed points. It should be non-rigid, that is, unable to support itself without its end supports, yet strong enough so that it can be stretched fairly tightly without breaking or permanently distorting.

Such a stretched, non-rigid strand will normally vibrate in smooth, regular, periodic patterns for a period of time after being displaced and then released, as with plucking. These vibrations, of course, are what we're after for musical purposes. There are three basic modes of vibration for stretched strings:

- 1) TRANSVERSE VIBRATION is vibratory movement in a direction perpendicular to the length of the string -- that is, movement from side to side.
- 2) LONGITUDINAL VIBRATION is comprised of waves of compression and rarification within the material of the string travelling along its length.
- 3) TORSIONAL VIBRATION is rotational movement of the string -- in effect, rapid repeated twisting and untwisting.

Modes 2 and 3 above are insignificant in the functioning of most musical instruments.<sup>1</sup> It is



mode 1, the transverse mode of vibration, that the great majority of string instruments are designed to take advantage of. The transverse mode is musically useful because it produces musical pitches throughout the hearing range using reasonable string lengths, and its movement communicates readily to soundboards and electric pickups.<sup>2</sup>

There are several practical physical principles that affect vibratory behavior in different stringing materials. We begin with a familiar set of relationships which theoretically apply to all strings, regardless of their material make up.

Three factors in interaction determine the frequency at which a string will vibrate when excited. They are vibrating length, tension, and linear density. Linear density is the mass of the string per unit length (M/L). The three variables are related to frequency as follows:

$$f \propto \frac{1}{L} \quad f \propto \sqrt{T} \quad f \propto \frac{1}{\sqrt{D}}$$

(The symbol  $\propto$  indicates proportionality and can be read as "is proportional to."<sup>3</sup>)

In other words, the longer or heavier the string, the lower the frequency and corresponding pitch; the greater the tension, the higher the pitch. The above equations make some idealized assumptions, and it is possible to refine them considerably by taking into account additional factors. But for the present purposes, they adequately express these important relationships. They also have the great advantage of being easily comprehended.

To these basics we can add a number of considerations which vary in their effect from one type of string to another. The following factors account for the differences between different stringing materials in practical application and musical effect.

INTERNAL DAMPING, or internal friction, refers to the degree to which vibrational energy is dissipated as heat in the material of the string itself. The rapid dissipation of energy associated with high internal damping leads to poor sustain. Since high frequencies suffer more than lower, the resulting tone tends to be rounder and less brilliant. Lead, for example, is a metal with a great deal of internal damping, and accordingly leaden objects produce a lifeless sort of sound when struck or otherwise set into vibration. Bell metal and spring tempered steel, meanwhile, produce sustained, ringing tones in part because they lose very little vibrational energy internally. For musical strings, it is usually preferable to have relatively little internal damping. On the other hand, in situations where excessively bright tone is a potential problem, more damping may be preferable. The classic example for this is harpsichords, which, with their sharp plucking mechanism and freedom from any **external** damping, are much prone to an overly bright sound.

The RIGIDITY of the material is important because it affects the pitch relationships of partials in the string's sound. Theoretically, for a vibrating string to produce a perfectly tuned overtone series, it must be infinitely flexible. If instead the string is relatively rigid, the overtones going up the series become progressively sharper than the ideal. For a very narrow string (which has relatively little rigidity) the problem is insignificant, but for bass strings (which must be thicker to achieve greater mass for lower frequency) it can be quite noticeable.

The effect can be heard in several ways: in metal strings (which suffer from rigidity problems more than softer types), it is likely to lead to a jarring, jangly tone. There may also be an apparent pitch drop following plucking, as the faster-decaying upper partials (sharp in pitch relative to the fundamental) fade, leaving only the fundamental and lower overtones. In bowed strings of very thick unwound gut or other soft materials, where higher partials tend to be fairly quiet, the inharmonicity of the overtones tends to further weaken the higher partials, since their conflicting frequency relationships don't reinforce one another. The result is likely to be dull tone, reduced overall volume and faster decay time.

Because the problem of inharmonicity is greater with heavier strings, rigidity is one of a complex of factors setting a lower limit on range for a given string length and stringing material. To alleviate the situation, various means for increasing mass without increasing rigidity have been devised. We will discuss them later.

TENSILE STRENGTH is the measure of how much stress a string of a given diameter can withstand without breaking.<sup>4</sup> There is a centuries-old consensus that strings perform best under high tension. At higher tension strings are less prone to pitch distortion resulting from transient tension increases due to forceful fretting and inadvertent bending, or over-forceful plucking or bowing (this is discussed in more detail below). In addition, if tension is high, then tension, rather than the string's own rigidity, becomes the primary restoring force that perpetuates the vibration by causing the string to swing back after being displaced to one side. Since rigidity is another factor leading to harmonic distortion, the restoring force of tension is preferable. In practice, however, the effects of negative factors associated with lower tension vary widely. Accordingly, the range of tensions over which a string of given length produces an acceptable tone likewise varies, and may in some cases be fairly large, depending upon the circumstance of its use. In any event, tensile strength is an essential consideration here, because it determines just how high a string of a given length can be tuned, in effect setting an upper limit on range. It turns out that a semitone's worth of increased range at the top corresponds to about an 11% difference in the breaking stress figure for a given stringing material.<sup>5</sup>

ELASTICITY refers to a material's ability to endure stress short of the breaking point without undergoing permanent distortion of form. Here we



are not so much concerned with the degree of elongation a material is capable of -- that quality is discussed under Elastic Modulus below -- but rather the range of tensions which can be applied without the string thinning out. Preferred stringing materials like steel, gut, and to a lesser extent nylon, can take tensions close to their breaking points without undergoing permanent distortion. Other materials may over time undergo distortion at tensions well short of the breaking point, in the heart of what would ideally be the playing range. These distortions have a tendency to occur irregularly, thinning out one portion of the string and not another, making for inharmonicity and a host of other problems.

ELASTIC MODULUS, or Young's Modulus, refers to a string's degree of stretchiness, or, more accurately, ability to resist stretching. It measures how much stress upon a string is required to create a certain amount of elongation. This factor turns out to have important musical consequences. To understand why, we'll first look at a related phenomenon.

When a string is sounded, it undergoes a temporary increase in tension -- in plucking, for instance, tension increases as the string is pulled to one side prior to being released. Since frequency varies with tension, this causes the string to vibrate initially at a higher pitch than the intended pitch. The pitch will then drop to a levelling off point as the amplitude diminishes. With bowed instruments, the sounding pitch remains sharpened as long as over-forceful bowing sustains high amplitude. This pitch distortion effect is very prominent when amplitude is large relative to other factors, for instance, in forcefully-played strings under low tension. (It can easily be heard if you slacken the strings on any standard instrument.) But under higher tension the effect is reduced to where it becomes virtually unnoticeable.

The pitch distortion effect, it turns out, also varies with elastic modulus of the material of which the string is made. Relatively stretchable materials (those with lower elastic moduli) can undergo normal displacement during playing with relatively less increase in tension, as they offset some of the tension increase by stretching. Thus, strings of more elastic materials will produce an acceptable musical result, with less pitch drop off, at lower tensions than materials with no give.

STRING SHAPE & UNIFORMITY: It is normal to assume that musical strings are of uniform mass and material, and are uniformly cylindrical over their full vibrating length. This need not necessarily be the case: strings which are not uniform in these respects will still produce recurring oscillations when excited. But in strings in which some of these properties change over their length -- strings which, for example, are thicker in one place and thinner in another -- subpatterns of vibration within the overall vibration will tend to have peculiar relationships. In other words, such strings will likely suffer from rampant inharmonicity. As discussed earlier in connection with overly rigid strings, this may lead to a

duller sound, or an odd, jangly and seemingly less "musical" sound -- or, if the irregularity is something extraordinary, it may just happen to produce an idiosyncratic but attractive timbral quality. (As an example of the latter, contemporary composers following John Cage's lead have found that strings which have been "prepared" with attached weights often give rise to an oddly appealing sound.)

Strings which are uniform in shape and size over their length may still differ from the norm by not being circular in cross section. Strings in the form of flat, strap-like bands, for instance, have been used and actually can be recommended for certain specific applications (more on that later). The vibrating behavior of strings of unconventional cross-sectional shape depends on the specific shape, and is not, to my knowledge, a subject that has been much studied.

Putting those exotic possibilities aside for the moment, almost all stringed instruments, as a practical matter, are designed with uniform cylindrical strings in mind. (Some types, such as overwound, twisted or woven strings, have textured surfaces and thus are not strictly cylindrical, but fine patterns such as these on a generally cylindrical form don't appreciably change the picture.)

However, when it comes to overall uniformity of shape, diameter, rigidity and tensile strength over the full length of a string, the practical reality is that some strings come pretty close to the mark and some do not. Marin Mersenne, in his 16th century musical treatise **Harmonie Universelle**, gave instructions for testing strings for uniformity prior to purchasing them or applying them to an instrument, much as today a clarinet teacher might give students instructions for selecting a good reed. (Mersenne's drawing, showing two pairs of disembodied hands demonstrating typical vibrating patterns for good strings and bad, can be seen on this issue's front cover.) Manufacturing standards have risen since Mersenne's time, and mis-shapen, irregularly overwound or otherwise faulty strings are not the every day problem for musicians they once were. But defective strings still do crop up, even among expensive brands of pre-packaged strings.

Strings of imperfect form suffer from all the problems of inharmonicity described above. And they lead to another problem for fretted or other stopped string instruments: by altering the frequency-determining variables for different segments of the string, their non-uniformity throws off the correspondence between string length ratios and frequency ratios. That in turn throws off the tuning of the frets or stopping points.

#### EXTERNAL INFLUENCES ON VIBRATING STRING BEHAVIOR

In this article we have proceeded as if no external factors were present and our strings were simply stretched, unimpeded, between two absolutely fixed points. That approach is useful for descriptive purposes, but it is, of course, an artificial ideal: in practice, outside influences inevitably enter the picture. The manner by which the string is excited, for instance, affects the vibrating patterns generated. Also important is

the influence of whatever holds the string: the way the string transmits energy to its carrier, the extent to which the carrier feeds energy back into the string, and the damping or interfering effects of bridges, frets and fingers, all make a difference.

We won't go further into these external factors here, since our professed concern is with string behavior in and of itself. But allow me to digress here for a moment to ask a tangential question: are there ways we can reduce the coloration from external resonators in order to actually hear something closer to "pure" string sound?

One way to do so is to make use of bone conduction. A string grasped between the teeth or pressed against the ear while held taut at the other end can be heard clearly with a minimum of intermediate filtering.

For a less restrictive approach, electro-magnetic amplification (using metal strings and an electric guitar pickup) goes a long way towards eliminating external coloration. Pierre-Jean Croset has gone a step further with his electro-acoustic strings by seeking out materials and body-shapes that are as acoustically neutral as possible. He has settled on a plexiglas-like plastic for this purpose. In general, using a very massive, rigid body (which the comparatively light string will scarcely move) should be effective in reducing absorption and feedback.

If one doesn't want electric amplification, the problem of preserving unalloyed string sound is more difficult, but one resonator material appears promising: rigid styrofoam. To the best of my knowledge, no one has ever studied the frequency-filtering properties of styrofoam. Subjectively speaking, however, one can say this: as a resonator for strings, styrofoam doesn't sound like wood, doesn't sound like metal, doesn't sound like an air chamber, doesn't sound like a membrane; it just seems to reproduce string sound, undiluted. Styrofoam also happens to make for amazingly efficient resonators (meaning loud). It's cheap and easy too, since a \$2 picnic cooler (attached to some sort of rigid stick to support the strings and take the stress) seems to work as well as anything, although it's not sturdy or long lasting.

## STRING DESIGN

The term "string design" refers to the art of deciding just what sorts of strings will bring out the best in an instrument. It is usually used in connection with pianos, harpsichords and harps, where the need for a great many strings covering a wide range demands careful and knowledgeable planning regarding string diameters, materials, and overwindings. "String scaling" is a closely related term, once again referring to the matter of establishing optimal relationships between lengths, diameters and so forth. The effects of poor string scaling are not trivial; they make a big difference in volume, timbre and stability of intonation. The situation seems to be most exacting on small fretted instruments, where exaggerated intonational response to minor tension fluctuations associated with normal fretting can drive you crazy. People who work in string scaling and design develop highly refined approaches,

using precise formulae and in recent years often looking to computer programs.<sup>6</sup> We will attain no such refinement here, but we will try to pull together some of the variables discussed in isolation above.

The most basic variables in string scaling are string length, string mass, and intended pitch. An instrument designer not bound by a specific tradition can manipulate these as he or she chooses. But one of the three, tension, is not always amenable to wide variation: the range of tensions over which a string sounds good varies depending on the circumstances, but is in some cases fairly small. It also happens that strings which are either very long and very thin, or very short and very fat, generally produce poor acoustic results. This means that a certain balance must be maintained between length and mass. And so the ideal approach to stringing a many-stringed instrument keeps tensions moderately high while manipulating both length and diameter to achieve the desired pitches, maintaining as much as possible a reasonable ratio of length to diameter all along the way.

With most existing string instruments, the string lengths are determined in advance by the traditional form of the instrument, and the pitches which those lengths are expected to accommodate are likewise given by tradition. The challenge in selecting the best strings, then, is to find the diameters that will put the strings at a workable tension when brought up to the desired pitch. And this tension should be uniform, or nearly so, across all the strings. This helps ensure that they will be in agreement in tone and "feel" (perceived response under the fingers), or at least reflect gradual transitions in those areas. To allow the builder to accommodate these subtleties, standard stringing materials are made in closely graded sizes.

As mentioned above, equations exist for working out acceptable scalings. On the other hand, trial and error can work too, if you have the following items in good supply: 1) strings of the desired material in finely graduated sizes, 2) common sense plus some familiarity with string instruments, and 3) patience.

And what are the factors determining the range of tensions over which a string of given length and diameter can produce an acceptable tone?

At the top end, we have seen, it is tensile strength -- the string's breaking point. The relevant ratio here is the actual stringing tension over breaking tension, or playing tension as percent of tensile strength. Most commentators on the subject seem to feel that the ideal playing tension for a string is as near as practical to the upper extreme. "Tune the top string as high as it can go without breaking" (or words to that effect) is the first instruction in more than one early treatise on string instrument tuning. (That instruction is a little like giving directions to the person next to you on the bus by saying, "Just watch me and get off the stop before I do.") But as a practical matter, however you determine the breaking point, some safety margin is needed between that point and the pitch to which the string is tuned. A standard formulation for that



margin is that the breaking point of the string should be about a tone or a tone and a half higher than the intended pitch of the string. Taking a different approach, a figure often given for steel strings is that they should ideally be set at about 70% of tensile strength. In this case, however, the conventional wisdom may be taken with a grain of salt. Much lower tensions can be acceptable and are actually desirable for nylon strings, which stretch and distort at tensions far below breaking tension.

The lower end of acceptable tensions for a given string is less clearly defined, since nothing so dramatic as string breakage enters the picture. Instead there are a couple of difficulties that increase as the string becomes more slack. One is reduced volume and an insubstantial tone. The other, as mentioned earlier, is the transient tension increases and resulting pitch distortion that happen very easily with slack strings. The question of how the instrument is to be played -- whether gently or in an aggressive manner -- is one factor in the severity of pitch distortion, and so also helps determine the acceptable lower limit of string tension. Harpsichords, for instance, may be strung at relatively low tensions if the jack's displacement of the string during plucking is modest. Whatever the instrument, the contact point of plucking or bowing makes a difference as well: pitch distortion is worse when the point of excitation is nearer one or the other end of the string.

One way to get around these limitations and increase potential range is by using strings of different materials on the same instrument. Recall that strings made of more elastic materials are less subject to pitch distortion because they partially absorb passing tension increases. As a result, they can produce an acceptable tone at lower tensions than other materials. These materials also tend to have comparatively low tensile strength, and so do not serve well at the upper end. Conversely, high tensile strength materials can take the stress at the top of the range, but sound worse lower down because they generally lack elasticity and are therefore more subject to pitch distortion. Combining the two types can increase potential range significantly.

Of course, range would not be a problem if we could simply use increasingly massive strings for the lower frequencies. Surviving depictions of early European string instruments show bass strings very much thicker than treble, especially on large instruments like bass viols. But such an approach is severely limited, since it leads very quickly to inharmonicity due to excessive rigidity in the string. This is the other major limitation on lower range, and for centuries upon centuries it severely restricted musical options.

In the face of the above mentioned problem, an important question in the history of string manufacture has been, are there ways to increase mass without increasing rigidity (and without at the same time reducing tensile strength too much)? Early string manufacturers in Europe addressed this question, and since some time around the turn of the sixteenth century several approaches have been devised.

One approach takes advantage of the fact that some materials are inherently less rigid than others. Such softer materials often have as well the advantage of lower elastic modulus, discussed a paragraph or two ago.

It also was noticed that several fine strands of stringing material brought together as one thick string is far less rigid than a single solid piece of the same mass and thickness. Thus, strings made of fine strands of nylon or silk thread twisted, woven or glued together have less inharmonicity than a single solid thick strand of material. With metal strings the same effect can be achieved by using many fine wires rather than one solid one, or even using two or three moderate sized wires twisted or woven together (the image of a few coarse wires looping about one another over the length of the string may seem odd, but such strings have been used.) With metals there is the additional advantage that drawing the material into very fine wire has the effect of work hardening it, giving the many joined strands greater strength in sum than an equivalent single wire.

In seventeenth century Europe the favored material for non-metallic strings was sheep gut. A single gut string is normally comprised of multiple fine strands of gut twisted into one. At some point it was observed that increasing the rate of twisting (the number of twists per linear inch of string<sup>7</sup>) further reduced rigidity. It also has the effect of reducing elastic modulus, i.e., making string more stretchable. This, as noted earlier, allows for playing at lower tensions without the usual degree of concomitant pitch distortion, thus further alleviating low-end stringing problems. It reduces strength too, but in the lower part of the range where tensions are modest, that is less important.

Djilda Abbot and Ephraim Segerman (cited in the preceding footnote) have experimented with strings made of twisted pairs of metal wires. Putting the tightest twists they could on pairs of various metals, they were able to extend usable downward range close to an octave in most instances.

Some early strings as well, as contemporary strings for some folk or non-western instruments, have twisting twisted again, with fine strands twisted into larger strands which are twisted or woven into still larger strings, much like heavy rope.

The greatest innovation in the pursuit of increased mass without increased rigidity came sometime around 1640. This was the invention, still with us today, of overwound strings. These are the strings, familiar to anyone who has played a modern string instrument, which are comprised of a core of strong wire or thread, tightly overwound with coils of finer wire. The idea behind overwinding is this: The core provides tensile strength, but, being itself not very thick, is not excessively rigid. The overwinding provides a great deal more mass, but, since the wrap easily compresses or separates slightly as the string flexes, it likewise adds little rigidity. As an additional advantage, overwinding achieves these things with a minimum of added internal damping. This combination of adequate strength, high mass and low rigidity is just what was sought; the



improvement in lower range tone quality was dramatic, and string instruments have not been the same since.

Overwound strings are usually made using a machine, which may be hand operated or motor driven. The principal component is a system for holding the core wire taut while rotating it at steady speed. In years gone by, the rotation was achieved by means of a counter weight and crank; that system is replaced nowadays by a motor. Then there must be means for feeding the overwinding wire from its spool onto the rotating core wire. Traditionally this has been done by hand, and people still do make individual strings this way. For the more automated machines used in larger operations today, there is a system for either moving the feed from the overwrap spool along the core wire as the winding progresses, or moving the core wire past the overwrap spool. String winding machines are usually made in-house by string manufacturers, either by designing and machining the parts from scratch or by converting an existing lathe. String winding machines have also been made by home craftspersons with the necessary complement of machine tools, skills and diligence. (I have been told that string winders are also made and sold commercially by a manufacturer in Germany, but have been unable to verify this or learn more.)

During the string winding process, the core wire should be stretched tightly; if not, the wrapping will separate when the string stretches on the instrument. (It should be noted here that widely spaced overwinding is also sometimes deliberately used). On the other hand, very recent investigations have suggested that holding the core wire under too great tension during wrapping can also cause problems: if tension during wrapping greatly exceeds playing tension, the wraps of overwinding wire will remain tightly compressed during playing and add to string stiffness, resulting in increased inharmonicity and pitch distortion.<sup>8</sup> A known, measurable and constant tension on the core wire during overwinding can easily be created by a simple arrangement of weights and pulleys. Some manufacturers do this; others use air cylinders or other means to put tension on the core wire. The overwinding wire should go on as tightly as possible, so that it fits snugly and the composite will behave as a single solid mass. As part of the bargain the overwinding gets some work hardening in the process, especially the outer surface which undergoes more stretching, making for a more durable string.

The relationship between the diameters of the core wire and the wrapping wire is important: the core must be big enough to provide sufficient strength, but if it is too big and the wrapping small, the resulting string will sound trebly and weak in the bass, and may suffer from inharmonicity. In thicker wound strings, a sleeve of fine nylon floss or thread may be included between the core and the overwrap, or between multiple layers of overwrap, to reduce wear and friction.

The wire used for the overwrap can be round in cross section shape, or it can be flattened -- oval or rectangular -- in order to provide a smoother surface on the finished string. Cylindrical

wrap, not surprisingly, tends to squeak more under fingers moving along the string. It also collects foreign matter in its crevices more readily during use. Recent studies appearing in the **Journal of the Catgut Acoustical Society** have confirmed that grime is a culprit in the aging of strings and the resultant loss of tonal brilliance.<sup>9</sup> Scanning electron micrographs reproduced in those articles -- fascinating to see -- show the presence of dirt between the winds of old, dull-sounding strings. Some manufacturers give their strings an abrasive polishing after winding; this has the effect of lowering ridges and filling valleys with metal particles, apparently inhibiting the build-up of foreign matter.

The several approaches to mass and flexibility discussed above -- use of multiple strands, twisting or braiding, and overwinding -- can be used in combination. Some modern strings have winding over a solid wire core; others have cores of finely stranded nylon, silk or gut. To some extent strings can be fine-tuned for a particular purpose, by bringing together strands of two or more different materials of selected mass, strength and rigidity. Some modern overwound strings, especially in the bass, have three or four or more layers, as, for instance, a bass string now being made by D'Addario, which uses a nylon core inside a sleeve of silk or nylon thread, wound over with a round copper wire, with yet another winding of flattened nickel over that. Still more elaborate is a bass string made in Czechoslovakia by Sonorex, which has a braided core of seven steel strands in a sleeve of nylon floss overwrapped with a spiraling layer of monofilament nylon overwrapped with a layer of circular copper wire, with a second layer of copper wound into the grooves of the first and polished flat on the outer surface, and a final layer of rectangular aluminum wound over that, also polished on the outer surface.

In this first half of a two-part article, we have tried to discuss, in a practical sort of way, the most important factors contributing to musical string behavior and certain basic elements of string design. This hopefully will provide some good background for the second half of the article, scheduled to appear in EMI's next issue. At that time we will leave the abstractions behind, and consider specific materials that can be and have been used in musical strings.

We will save the bibliography for the end of part 2, but I will take the opportunity here to credit the most prominent among the many individuals who contributed to this two part article, with specific information, leads to further sources of information, and criticism of the manuscript:

Sincere thanks to Professor Donald Hall, Scott Odell, H.E. Huttig, Donna Curry, Mark Emery Bolles, Lyn Elder, Brian Godden, Bob Archigian, Walter Lipton, Bill Monical, and David Eisner.

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(See the following page for footnotes.)

<sup>1</sup>Mode 2, longitudinal vibration, is used in some friction drums with strings (these are chordophones often misclassified as membranophones). It also sometimes can be heard as a special effect with conventional string instruments, achieved by squeaking a smooth string or scratching an overwound one. But in order for longitudinally vibrating strings to behave harmonically and dependably produce predictable pitches within the hearing range, the string must be extraordinarily long -- like forty, sixty, or a hundred feet, depending on the material the string is made of. That is because of the speed at which soundwaves travel in solid materials strong enough to be strung up and put under tension. This phenomenon has been explored by Ellen Fullman with her Long String Instrument, described in EMI Vol. I #2.

Mode 3, torsional vibration, has virtually no audible effect if the string is cylindrical (as most are), because whatever rotational movement may arise stores very little energy and has little "grab" on bridges, soundboards, electrical pickups, or surrounding air (however, such vibration may have some effect in mechanics of the "stick-slip" action by which bowing a string induces vibration). Torsional vibration may play a role in the effect of some instruments with strings shaped differently in cross section, such as flat, strap-like, band-shaped strings.

<sup>2</sup> For the sake of completeness, we should perhaps outline one more characteristic here: the musically useful vibrations we are talking about here are the kind of regularly recurring oscillations commonly called "standing waves." By contrast, strings that variously combine factors of great length, little rigidity, and/or low tension may produce as their predominant movement pattern a travelling wave which can be seen running along the string like the hump in a loose-ended rope that has been given a shake. (Such waves can still be considered transverse vibrations, since the movement of any individual point in the medium is side to side, even though the cumulative effect is of longitudinal movement.) With the string lengths, tensions and stringing materials that are at play in most stringed instruments, this progressive movement still occurs, but very rapidly, in pairs of waves which repeatedly reflect off of the string's end supports and back upon themselves. The cumulative effect of such motion for any given segment of the string is regularly recurrent patterns of oscillation. These patterns are often called standing waves because they do not appear to travel. Remember, though, that they are manifestations of travelling waves, seeming to stay put only because of the manner in which repeatedly reflected traveling waves interact at individual points on the string.

<sup>3</sup>We could have used equal signs in these formulas by inserting proportionality constants, as, for instance,  $f = K(1/L)$ . The actual value of the constants for the three formulas would depend upon the units of measurement being used.

<sup>4</sup>Strings actually go through several stages of response to increasing stress prior to breaking. For a more complete description of these stages and their practical implications for musical strings, see Mark Bolles' article "Harpmakers Notebook #10 -- Real Strings" in *Folkharp Journal* #65, Summer 1989.

<sup>5</sup>Tensile strength is measured in pounds per square inch (or other units for weight & area). This represents the stress required to break the string divided by the string's cross sectional area. Early investigators, notably Marin Mersenne, measured string strength simply by measuring the load required to break the string, to get a result analogous to the test strength indication used today to grade nylon fishing line. Tensile strength can be derived from the simpler breaking load measure by factoring in string diameter in the form of cross sectional area. The practical difference between the two approaches is that breaking load measures the strength of a particular wire, while tensile strength purports to measure the strength of a given material independent of its actual configuration.

The 11% figure mentioned here for relating breaking stress to functioning range was arrived at by Abbot & Segelman, apparently by empirical means, and noted in their article "Strings in the 16th and 17th Centuries." The mathematically predicted value would be closer to 12%.

<sup>6</sup>A good source for computer-aided string design software or related consulting is Mark Bolles of Markwood Musical Instrument Makers, 1250 N.E. 5th St., Bend, OR 97701, phone (503) 389-6775.

## SPIRIT CATCHERS AND WINDWANDS (Music in Circular Motions)

By Darrell De Vore

This is the third and final article in *Experimental Musical Instruments'* series on instruments sounded by whirling or circular motions. In the first article we heard tell of the dozens of diverse instruments used by the ensemble *Whirled Music*, described by David Toop and Max Eastley. In the following issue, Sarah Hopkins discussed the role of whirled corrugated tube instruments in her music. We hear now from Darrell DeVore, northern Californian builder of all manner of instruments from bamboo [see EMI Vol. III #4, "Bamboo is Sound Magic"].

Spirit Catchers and Windwands began their evolution twelve years ago when I first got my hands on a "Buzzing Bee", a Chinese toy made of two bamboo slices mounted on each end of a short length of wooden dowel with a flat rubber band stretched tightly around the rounded bamboo end pieces. A length of string is attached to one end and cardboard wings are stapled to the center post. The whole structure is no more than four inches in length. When whirled in the air by the string, it does sound like a bee. (These toys are still available in Chinatown and at the Exploratorium Store in San Francisco.)

I was delighted to discover a simple universal principle of sound at work in this toy. I was familiar with free-air idiophones such as bull-roarers, outer-air aerophones like metal and bamboo bird whistle cylinders on a string, and plastic corrugated tube whirlies. The Buzzing Bee is a free-air chordophone, the stretched rubber band playing the sound role of a tensed string or chord. It is related to the Aeolian Harp with its

<sup>7</sup>A standard measure for the rate of twisting is the twist ratio, defined by Abbot & Segerman as the distance along the string for one 360 degree twist divided by the string diameter. (Djilda Abbot & Ephraim Segerman, "Strings in the 16th and 17th Centuries," *Galpin Society Journal* xxvii, 1974)

<sup>8</sup>Norman C. Pickering has investigated this and reports on it in "Nonlinear Behavior in Overwound Violin Strings" in *Journal of the Catgut Acoustical Society* Vol. I #3 (Series II), May 1989. The ideal wrapping tension, he concludes, is not much greater than playing tension, allowing the wraps to separate by a microscopic amount during playing. These questions are less important for strings of highly inelastic materials like steel, since for these the amount of stretching during both wrapping and playing is miniscule.

Pickering gives the following figures for tensions during winding and playing on two commercially manufactured violin D strings: For a heavy gauge Perlon core string with two layers of overwinding, winding tension was 15 pounds and typical playing tension 12.5 pounds, or 85% of winding tension. For a lighter gauge Perlon core string with just one layer of winding, winding tension was the same 15 pounds; playing tension 8.8 pounds or 59%. The latter string, according to Pickering, suffered the problems of inharmonicity associated with excessive winding tension.

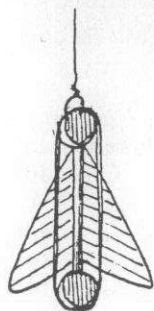
<sup>9</sup>Roger Hanson, "Analysis of Live and Dead Guitar Strings", *Journal of the Catgut Acoustical Society* #48, November 1987.



# INSTRUMENTS

stationary strings moved by wind to sound. However, with the Buzzing Bee, the chord is moved through the air with windspeed controlled by the player.

My mind took flight immediately. I made a larger version of the sounding body of the Buzzing Bee using big bamboo slices and a twelve inch length of 1/4 inch wood dowel as a center post, with a No. 64 rubber band stretched flatly around the frame.



Buzzing Bee

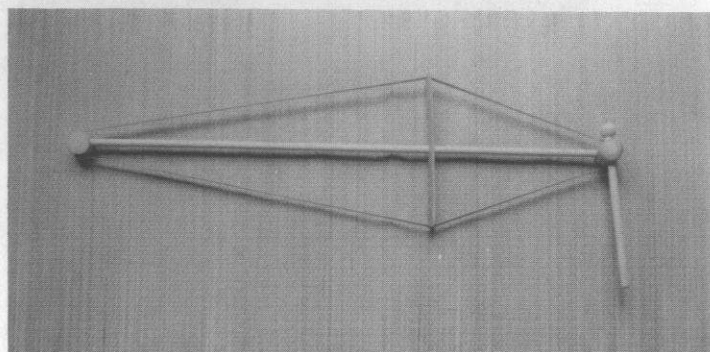
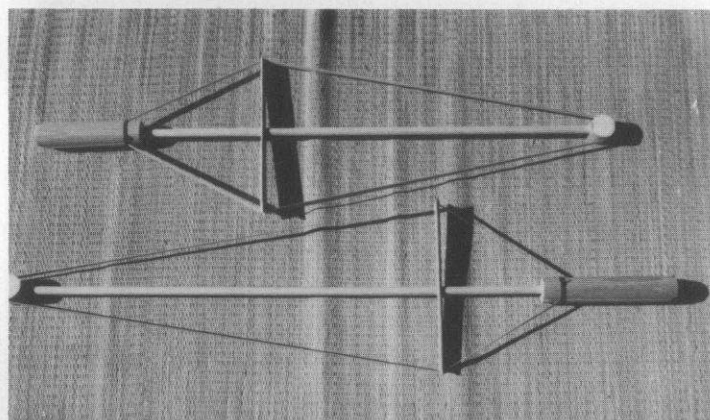
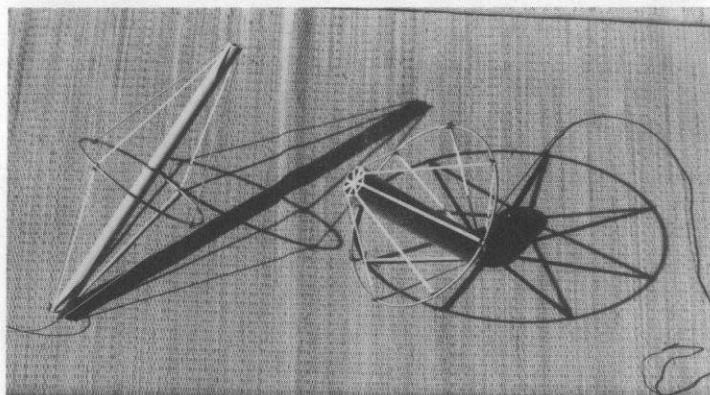
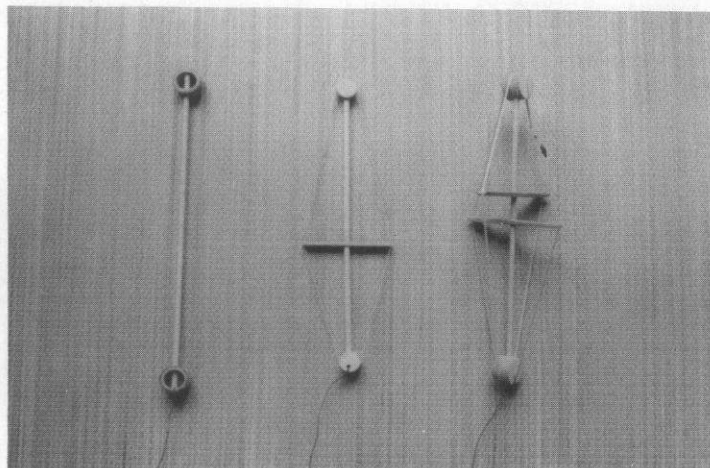
Tying a length of string to one end, I swung it in circles, surrounding myself with a new world of sound. This device had a much richer musical sound than the monotonous Bee ... a strong fundamental tone with dense harmonic overtones. Because I had left off the cardboard wing (designed to stabilize the flight pattern so the Bee tone would be continuous) this new instrument had amazing variables in its sound letting. Long tones were interrupted by staccato rhythmic patterns intermixed with strange

vibratos and unusual spatial phasing. At hand was an entrancing new music form with unlimited possibilities.

The Buzzing Bee evolved into the much larger Buzzers, then into Hummers, which have elongated end pieces and use multiple rubber bands (a version of the Hummer is pictured in **The Book of Bamboo** by David Farrelly, Sierra Club Books, 1984). D-Trads (don't ask about the name) came next, extending the Hummer idea with the addition of bridges. The moveable bridge was devised to fit on the center post, giving the rubber band more tension, some pitch tuning capabilities, and doubling the number of fundamental sounds produced by the rubber band from two to four. This led to a series of modular, multiphonic free-air chordophones that acquired the name "Spirit Catcher" (Shamanistic musical instruments that act as receptors for unseen spirits). The name stuck and all the string-swung chordophones I makes are now called Spirit Catchers.

## Windwands

Windwands evolved from Spirit Catchers. The original idea came out of necessity. Making Spirit Catchers with kids presented certain dangers created when whirling them in the confines of a classroom. To get a handle on the problem, I put a handle on a Spirit Catcher, and solved the problem of Spirit Catchers flying out of hand and strings breaking. A handle allows for control of the direction, speed and velocity of the sound



PHOTOGRAPHS THIS PAGE

Top: 3 Spirit Catchers -- Buzzer, D-Trad & Spirit Catcher  
2nd from top: 2 Circular Spirit Catchers.  
3rd from top: Early Windwand Design.  
Bottom: Revolving Windwand

Photos by Darrell De Vore



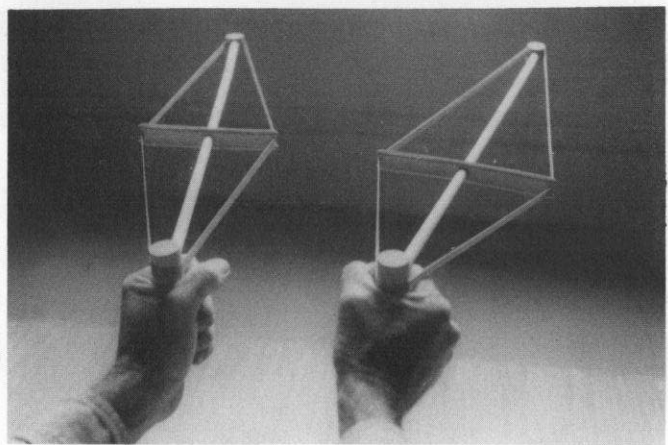
source, and demands less space for playing. In order to attain a maximum efficiency in making sound with this instrument, a player must learn to make precise movements in the air. It is like a sword or wand in the hand. Thus the name, Windwand.

Windwands went through many permutations on the way to their present design. The first models had vertical handgrips on one end like a tennis racket. The present handle is like a pistol grip, held in one hand with the Windwand pointed away from the players' body. Moving the wrist and forearm up and down in graceful, even strokes will produce good sound. Short strokes produce short, rhythmic sounds. Tracing great arcs, figure eights and circles in space produce longer tones.

A breakthrough in the Windwand design came in 1986 when I devised an insertable spinner handle that fit through a hole drilled in the stationary handgrip, allowing the Windwand to revolve in continuous circular motions and producing a wonderful long-toned mandala of sound.

Although Spirit Catchers and Windwands produce the same sound phenomena using the same principle, basic structures and materials, they are quite different from each other to play. With the handle, Windwands can be totally controlled by the player. On the other hand, Spirit Catchers are wild things flying on the end of a string. The player can control only the speed of the flight. Both types of instrument are capable of a wide dynamic and harmonic range of sound. Minimal motion sounds the fundamental frequency of the stretched rubber bands. When speed and intensity increase, amplitude increases and harmonic overtones are sounded. At maximum velocity, a high frequency buzz of angry white noise occurs, dominating the musical sounds. This is a breaking point and should not be sustained.

The principle behind these free-air chordophones is workable at any size and with any prac-



Windwands held in "stroking" position.

tical materials. I have made these instruments in sizes ranging from six inches to six feet in length. In place of rubber bands, I've been experimenting with vinyl recording tape, which produces a flat trumpet-like tone with almost no harmonics. I also want to try various types of cloth tape, metal tape, guitar strings and piano wire.

### Stirring Things Up

Spirit Catchers and Windwands are meant to be accessible musical sound sources for all people, and are gradually spreading over the world. I have made hundreds of these instruments with children in workshops, music camps and elementary schools in Northern California. I've used them extensively in new music forms with ensembles in Canada, Hawaii, San Francisco and Telluride, Colorado. They've played in New York City and Europe. They've been used in theater, dance, rituals, parades and performances. Composer/Sound Artist Sarah Hopkins took them to Australia and

adapted them to use in her music. The poet Nanao Sakaki took the Spirit Catcher to Japan where it sounds as a symbol of peace for a growing world peace movement. In August, I did a two-week residency at ArtPark in Lewiston, New York, making Windwands with the public. In that time, with the help of three fine assistants and the staff at ArtPark, we made 2,330 Windwands.

There is a functional beauty to all free-air musical instruments that is universally recognized. They are the very embodiment of freedom. They must have unobstructed open space in order to function. They extend human contact with the element: Air. They are meant to play new music, to call the wind, to

Photo by John Fago

Darrell De Vore with a multiphonic circular free-air chordophone, producing 36 fundamental tones.



bring the rain, to sing to plants, to talk to  
ancestors, to catch spirits, to unite the world,  
to heal the planet,  
to stir the sky.

## HOW TO MAKE A WINDWAND

Tools: Saw, drill & bits, round file, sandpaper.

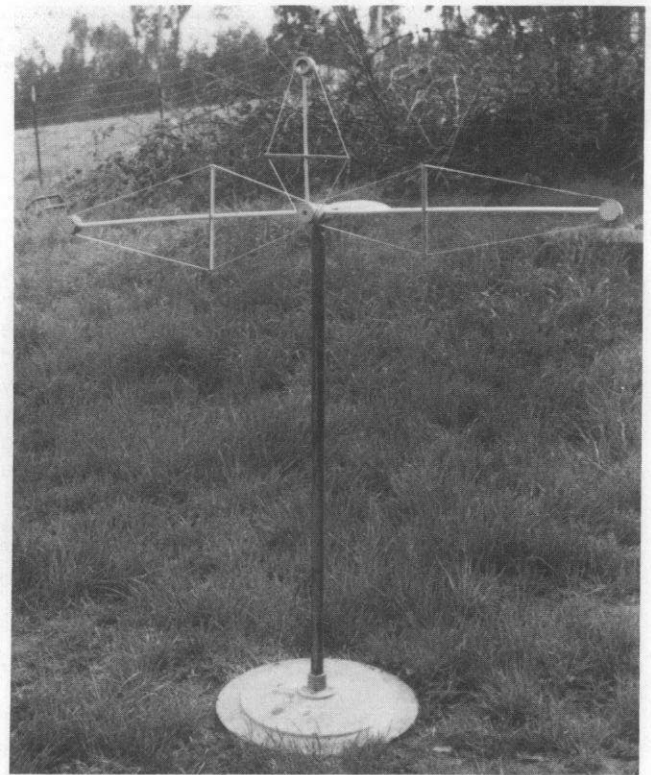
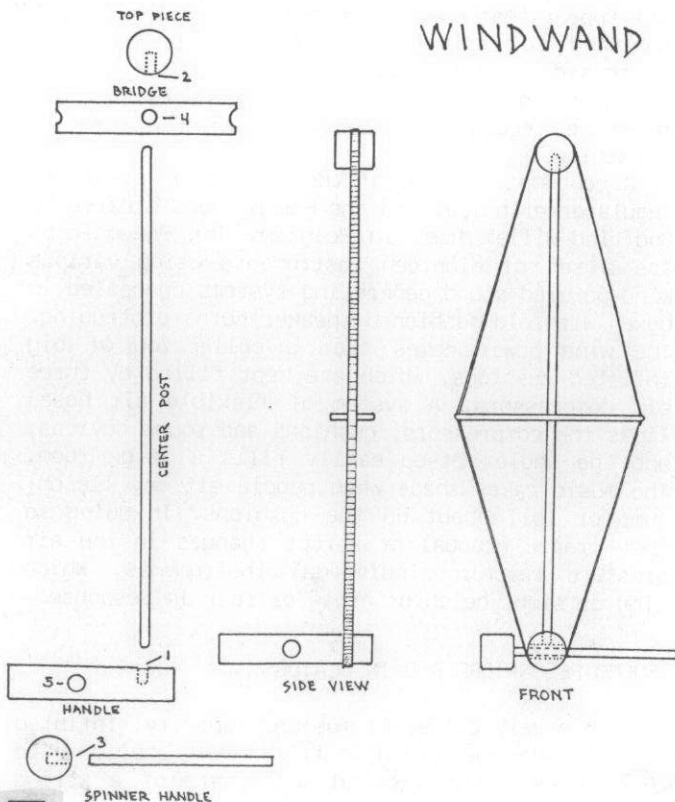
Materials: 1" wood dowel, 1/4" wood dowel, 3/8"  
wood dowel, 3/4" thin wood lath.  
Rubber bands.  
White glue.

Cutting: Using 1" wood dowel, cut 5" length for  
handle. Cut two 1" slices for the top piece  
and spinner top.  
Using 1/4" wood dowel, cut 12" length for  
center post. Cut 6" length for spinner handle.  
Cut 5" length of lathing for bridge.

Drilling: Using 1/4" drill bit, drill center post  
hole in handle (1).  
Drill hole as shown in top piece (2).  
Drill hole in spinner handle (3).  
Drill hole in center of lath piece for  
bridge (4).  
Using a 3/8" bit, drill hole completely through  
handle center, straight and perpendicular to  
hole no. 1 (5).

Use sandpaper to get rid of splinters and smooth  
the rough edges of the large dowel pieces.

Use the round file to make rounded grooves at each  
end of the lath bridge.



Wind Directional Free Air Sculpture by Darrell De Vore

## Assemblage:

1. The Spinner Handle: Fit and glue the 6" length of 1/4" dowel into the hole in 1" dowel.
2. Fit center post end into hole (1). If fit is tight and secure, glue is not necessary.
3. Slide bridge onto center post through hole (4) in center of bridge.
4. Fit top piece (2) on to center post so rounded side parallels rounded side of handle.
5. Take a single No. 62 or No. 64 rubber band (these are widely available in office supply and stationary stores), and stretch it between your two thumbs to make sure it is sound. Fit the rubber band flat around the center of the top piece, holding it in place as you stretch it around the handle right below the center post. Rubber band should be flat, untwisted all around and perfectly parallel with the center post.

Now move the bridge near the center of the vertical post and toward a position perpendicular to the handle, while placing each side of the rubber band in the grooves in the bridge. Adjust the bridge and rubber band tension. It should be secure around the top piece and handle.

The windwand is now ready to sound when moved correctly with the hand.

The spinner handle can be inserted through the hole in the handle for revolving motion.

## BALLOONS & BLADDERS

By Bart Hopkin

(continued from page 1)

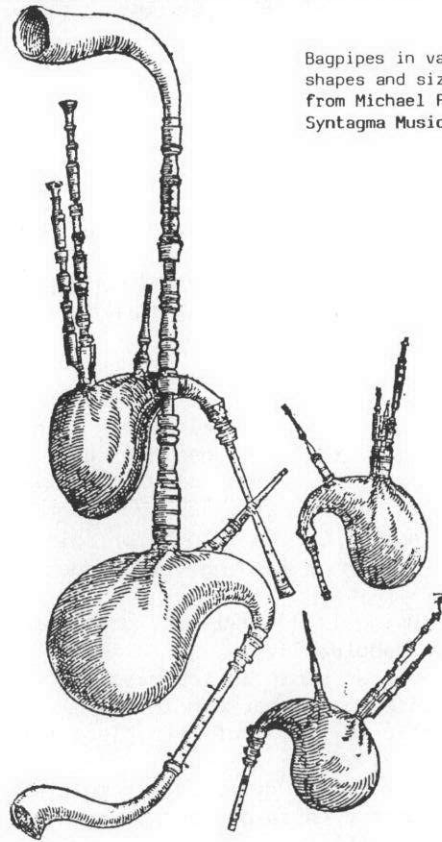
and the functioning of the bag. The sound of a bagpipe is created by the chanter, a reedpipe with toneholes, plus, in most cases, one or more drone pipes. These are attached to an air-filled bladder, and air is forced through them by squeezing the bladder under one arm. Typically the bladder is filled either by the player blowing through a blowpipe with a one-way valve, or by a small bellows operated by the other arm. The bladder serves as an air storage system, a pressure equalization system, and, with the aid of the player's squeezing, a pressure generating and control system. You could say, it takes the player's AC breathing and converts it to a DC airflow. This is why bagpipes can drone interminably without having to stop for breath.

As mentioned above, animal bladder has been common historically, but any number of materials can serve for the bag: both bladder and stomach from larger animals have been used, as well as whole skins of smaller animals. The natural apertures -- limbs and necks in the case of skins -- are usually used to admit the pipes. More recently both rubberized cloth or sewn sheepskin have often been used. The bag must be air tight, of course, but it helps if it can at the same time absorb and pass moisture. Otherwise with mouth-blown pipes water collects and damages the reeds. Rubberized cloth bags, which lack this property, must have drain plugs if they are mouth blown.

A less elaborate relative of bagpipes is the bladder pipe, used in Europe during the middle ages. Although it became obsolete in most places during the renaissance, it survives still, sometimes in degenerate forms, in a few scattered locations. It was an early form of reed cap instrument -- that is, a wind instrument possessing a reed enclosed by a covering so that the player's

SHEEPSKIN  
BAGPIPE

Stipple  
drawings  
by Robin  
Goodfellow



Bagpipes in various  
shapes and sizes,  
from Michael Praetorius'  
Syntagma Musicum (1620)

mouth did not directly contact the reed. The covering in this case was the small bladder, with a short blow pipe attached. By blowing into the bladder, air was forced through the reed and thence through the main pipe, which was played like other woodwinds with toneholes. From surviving depictions of early bladder pipes it does not appear that the player manipulated the bladder by hand to control air pressure. It may have possessed some balloon-like flexibility though, which could have allowed for a degree of air pressure regulation independent of the player's breathing.

A contemporary use of the bladder-as-pressure-regulator principal are the Pneumafoons created by Godfried-Willem Raes in Belgium. The Pneumafoons are a set of eighteen instruments using various wind-powered sound generating systems concealed in boxes with old fashioned speaker horns protruding. The wind power comes from a collection of big inflated cushions, which are kept filled by three air compressors. A system of flexible air hoses links the compressors, cushions and sound devices, and the whole set-up easily fills a large room. The music takes shape when people sit on, lie on, jump or loll about on the cushions. In doing so they create gradual or abrupt changes in the air pressure reaching individual instruments, which sing or sigh, belch or groan or roar in response.

## SOUND RESONATORS AND INSULATORS

In a very different musical capacity, inflated membranes can also fill a role analogous to the sound box and soundboard of a string



instrument. In this application, they absorb vibrations from an outside source, such as a string or some idiophonic material, and radiating them to the surrounding air. In fact, the surface of an inflated membrane is in some ways quite well suited to the task of sound radiation. It is usually a large surface (compared to, for instance, a string, which has relatively little surface area), which enables it to move a lot of air -- the first requirement for an effective sound radiator. It is also usually light and flexible, which allows for ready response. It might be found too flexible -- there are disadvantages to that -- but its inflation imparts at least some degree of rigidity and restoring force.

I am aware of only one traditional instrument type that uses an inflated bladder this way. That is the bladder and string, in its various manifestations as bumbass, basse de Flandre, muzy-cyny, smyk, et al. Bladder and string is a European instrument, associated with beggars and wanderers, now quite rare but apparently still surviving. It is comprised of a stout stick about four or five feet long, with an inflated pig's bladder situated near the lower end. A single string (possibly more than one on an earlier version of the instrument) runs end to end, stretched over the bladder, which serves as a sound radiator. It is played with a bow or a notched stick, normally as a drone of unchanging pitch.



**BUMBASS**  
Drawing from an engraving in  
Ballads and Songs of Derby-  
shire by L. Jewitt (1867)  
(New Grove Dict. of Musical  
Instruments; British Museum).

More recently, inflated membrane resonators have been used by the Baschet Brothers in France. And this takes us to the second main topic for this article, balloons. Starting in the early fifties with an inflatable guitar, the Baschets used balloons in a capacity similar to that of the bladder on the traditional bladder and string. (This is a case of polygenesis -- the Baschets' idea was arrived at independently and was not derived from the traditional instrument). They continued to use balloon sound radiators in both idiophonic and string instruments for a decade or so, before shifting to the metal cone resonators that ultimately proved more effective, and that have since become one of their trademarks. For a complete discussion of this aspect of the Baschet Brothers' work, see EMI Vol. III #3.

At the same time, balloons proved effective for another purpose in the Baschet instruments: that of vibration insulators. For many idiophones, there is a recurring problem as to how to hold the vibrating object in place without damping it at the same time. Often it seems like the only effective way to allow a sounding object to vibrate freely is to throw it up in the air and let

it sound in free fall. It turns out that one very successful means for holding things without inhibiting their vibration is to rest them on balloons, which act like a portable air cushion. Since balloons are so very elastic and yielding, and in most cases so much lighter than whatever it is that contacts them, their damping effect is miniscule. They sometimes bring out unforeseen potential in an idiophonic sounding object that otherwise would have been unattainable.

Balloon insulation mountings have also been used extensively by a couple of San Francisco builders, Tom Nunn and Chris Brown. Tom's Crustacean (described in EMI Vol. I #4) is one example. It is comprised of a 3' stainless steel disk, with a set of upright metal rods brazed onto it and played with a bow. The disk rests on three balloons, set in buckets for stability. Mounted this way, the whole system reveals a degree of acoustic life -- that is, great resonance and sustain, not to mention a certain playful wobbliness -- that could not have been realized otherwise. The photograph here shows another very simple but highly effective balloon-mounted sound instrument, consisting of a single long steel percussion bar on a balloon in a bucket.

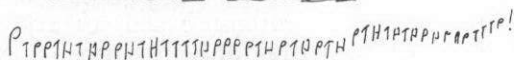


#### SQUEAKS, RATTLES, RAZZERS AND BLOWERS

Inflated balloons can be used as primary vibrators in a few ways. For one, as everyone knows, they can be sounded by friction. Finger squeaks usually work well. Rosin doesn't seem to make much difference but a little moisture can help them speak more readily and forcefully. It's also possible to make tiny balloonlets from scraps of balloon rubber, an inch or less in diameter, and squeak them against the moistened palm of the hand. The smaller and tighter the balloonlet, the higher the pitch.

Less well known are balloon rattles. Simply by placing small pellets of some sort -- rice or dried beans, for instance -- inside a balloon before inflating and tying it, you create a rattle with a deep drumming sound of surprising richness and presence. A similar effect can be achieved using balloon rubber stretched over the open ends of a tin can with the top and bottom removed, or any similar short, wide tubing material.

We have been speaking of inflated balloons. Let us now untie one and let the air out. The balloon rushing crazily backwards around the room, producing its comical raspberry sound, is acting as a bilabial -- a sort of floppy oboe reed in reverse. As it spews out its air the opening acts



Prior to snipping off its body, the balloon was simultaneously serving another musical function, which could potentially be given broader application: it was acting as a means for storage and release of potential pneumatic energy, somewhat similar in function to the bladder on a bagpipe. Some toy reedpipes use balloons in this way: one blows up a balloon, and then, without releasing the air, stretch the mouth over the opening of a pipe with an enclosed internal reed (another reedcap instrument). Ted Goodfellow (classical woodwind player, unfettered musical spirit, and father of EMI's Robin Goodfellow) used to apply a similar compressed air system to an ocarina in light musical entertainments. He would finger a short melody on the self-playing instrument thus created, and at the last note release the mouth of the balloon with a flick with the thumb, for a jet-propelled, sputtering send off.



Having now released the air from the balloon, we can move on to some of the possible uses of uninflated balloon rubber membranes. Of several people who have explored this area, one stands out and deserves special mention: It was Prent Rodgers who conceived the balloon flutes described here, as well as developing the ideas of both blown and plucked membranophones of balloon rubber.

On the other hand, perhaps due to the very same qualities of lightness and compliance, balloon rubber responds well when placed over a resonating air chamber, such as a long narrow tube. Some degree of coupling between the vibration of the membrane and the air chamber is fairly easily achieved, and the resulting sound can be quite pleasant. The fact that such drums are cheap and easy to make adds to their attractiveness.

Balloon drums have often been made as tube drums in tuned sets much like boobams. Any sort of tubing can be used; plastic pipe of two or three inches in diameter is common. It may be any length from a very short four or six inches to two or three feet, depending on the desired pitch and tone. A fresh, large balloon is cut and stretched over the top. If the balloon is the right size and shape and is cut right, then nothing more is needed to hold it in place -- it will fit snugly over the tube and stay by friction. If there is a lot of extra balloon running down the pipe it can be neatly rolled up on itself part way to form a



AT LEFT:  
Pneumatic  
energy  
storage  
and deliv-  
ery system,  
with reed  
attached.



sort of collar. If the drum is to be part of a multiple set, some sort of stand and mounting system must be made to hold the drums in the desired positions. Balloon drums sound best with a very light weight beater having a fairly soft head.

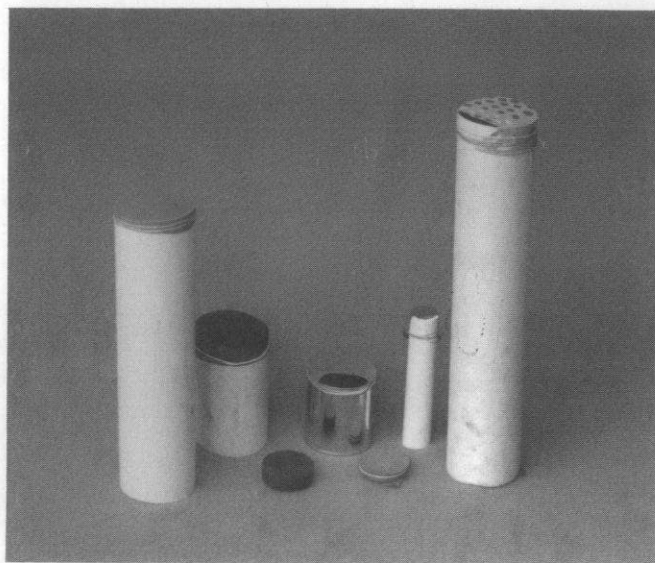
Ensuring uniform tension over the surface of the membrane makes a noticeable difference in tone quality. If some portions of the membrane are more tightly stretched than others, conflicting frequencies within the membrane work at cross purposes, reducing resonance.

Tuning need not necessarily mean setting the membrane and the air column to the same fundamental. Other relationships can generate the resonance that comes with some degree of coupling between the two. Many possible relationships between the rubber drum head and the air column produce interesting timbral qualities, sometimes with distinct multiple pitches. Even simply leaving the tunings random can make for a pleasant effect, especially since the several drums will then have not only different pitches but distinct timbres as well.

A unique facet of balloon drums is that they need not be played by percussion exclusively. The lightness, flexibility, and traction of the balloon rubber allows for some additional possibilities. Other membranophones just can't do some of these things.

For one, balloon membranes can be plucked. This can happen two ways. In one case you begin with a normal membrane, such as would appear on the balloon drums described above. The surface of most balloon rubber has enough traction that, if it is fairly loosely stretched, you can press your finger into it and draw it back, hooking some of the rubber over the tip of your finger in the process. The pluck comes when you let it snap back. In the other case you begin with the membrane set differently on the tube. It is not stretched fully over the opening, but left covering something more than half, with one edge remaining free but stretched tight across the aperture. This edge can easily be plucked with a downward motion of the fingers, very much like plucking a string. This second method is much easier to execute, and to my ear produces a clearer sound. The resulting tone in either case is timbrally similar to the struck tone of the same membrane, but the attack is sharper, with an unmistakable plucked quality. The sound emitted from the far end of the tube, especially at close proximity, is really quite appealing, with very well-defined pitch (if the drum is well tuned) and good sustain. The sound from above has a larger component of pluck noise and, to my ear, isn't as attractive. [Question: can these techniques really be called plucking? Answer: if it feels like a pluck and sounds like a pluck, it's a pluck.]

Believe it or not, stretched balloon rubber membranes can also be sounded as a wind instrument. Here's how to sound the little-known aeromembranophone: The player holds the drum body and membrane up to his or her lips. The lips are pursed, in a manner similar to flute playing position. The rim of the drum touches the jaw or



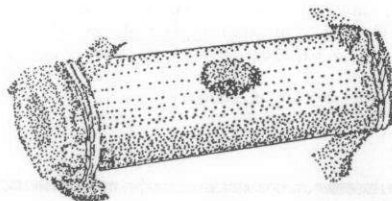
BALLOON MEMBRANOPHONES. These can be struck or blown; those with partially open membranes can be plucked.

lower lip, which is drawn inward slightly, while the upper lip reaches over the surface of the membrane, touching it lightly, and in this position the player blows. It may take a few tries to get the knack, but eventually you'll hear the sustained sound and feel the tickle on your upper lip. It is a difficult sound to control, and often comes out as a high shriek, sometimes featuring two dissonant pitches torturing one another. But with a mix of luck and skill, lower tones can be produced from the same membrane, with, at its best, a pleasing, strong yet veiled trombone-like quality. With larger membranes and lower tones, the sound continues with a gradual decay after the blowing has stopped.

These blown membranophones have often been made using nothing but an inverted jar lid (such as the top from a mayonnaise jar) with balloon rubber stretched across. But to reduce squeakage and bring out the attractive lower tones, it is very beneficial once again to use a tube drum arrangement, with the membrane stretched over a tubular resonating chamber and the two components tuned for effective coupling. Large membranes, stretched over an opening of six inches or more, work as well as small ones of two inches or so. It is especially important in this application to stretch the membrane uniformly to avoid conflicting responses in the membrane.

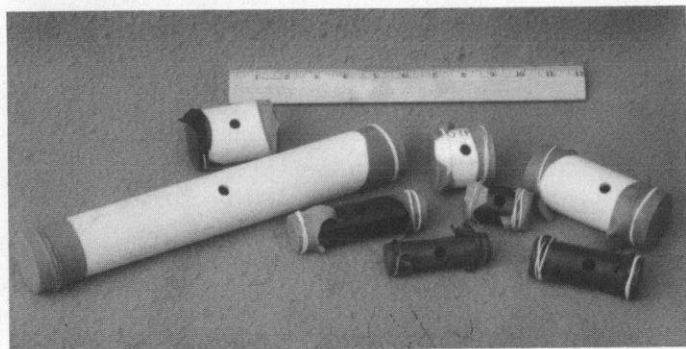
#### BALLOON FLUTES

Also sounded by air are Prent Rodgers' balloon flutes. These are short, fat tubular transverse flutes with the blowhole not at one end but at the midpoint. Any reasonably rigid material may be used for the tubing. Balloon rubber is stretched



and fixed over the two ends (rubber bands will do to hold them in place). There are no toneholes. The player sounds the instrument by blowing across the blowhole in normal flute fashion. In this unique arrangement, the pitch appears to be determined primarily by the rigidity of the tube ends. With both tube end balloon membranes untouched, the flute's lowest note sounds. Lightly touching one end (thus reducing its flexibility) raises the pitch; touching both raises it still more. Touching either or both more firmly also contributes to rising pitch, in part apparently because doing so further increases rigidity, and in part because pressing harder tends to press the membranes inward, reducing the enclosed air chamber volume.\*

The maximum possible range of these flutes depends in part on the ratio of flute length to width, as that ratio corresponds to the ratio of rigidity-controllable wall area to overall size: a flute with a smaller component of wall area to be manipulated will naturally have a smaller range. Maximum practical range seems to be about a major sixth, fully continuous. With some limitations an octave can sometimes be achieved. The tone is a quiet, pleasing, hooty flute sound, long on fundamental and short on overtones, much like some globular flutes. Balloon flutes may be tiny -- less than an inch in diameter and two inches long -- or up to over a foot long.



BALLOON FLUTES large & small.

## THE END

Are there more musical things remaining to be done with balloons and bladders? Undoubtedly. But I have come to the end of my list. If I've missed your favorite, write EMI about it and we'll add a footnote in a future issue.

\* Professor Donald Hall, to whom EMI often turns for knowledgeable acoustic analysis, confirms this general description, and goes on to say:

If the "acoustic reactance" of the membrane is characterized as  $X$ ,  $Z_c$  is the impedance of the air column and  $L$  is the length of the half-pipe from mouth hole to end, and compared with the acoustic impedance of a long column of air,

$$Z_c = \frac{\rho c}{A} = \frac{(\text{density of air}) (\text{speed of sound})}{\text{pipe cross-section area}}$$

then natural frequency should be roughly

$$f \approx \frac{c}{2\pi L} \arctan \frac{X}{Z_c}$$

# INSTRUMENTS

## The Protracted History of THE BELLOW MELODICA

By Bob Phillips

This article originally appeared in **Keep Pickin'**, newsletter of the Tri-State Folk Music Society.

The instrument described below has been dubbed "The Bellow Harmonica". Strictly speaking, a **bellows** is a device for producing a stream of air under pressure. And a **bellow** is any loud sound made by powerful uttering (as a bull, elephant, etc.).

So it would follow that the instrument would properly be referred to as "The Bellows Melodica"; but that doesn't roll off the tongue as well. Besides, if you've ever heard the thing being played, images of bulls and elephants uttering powerfully might well come to mind.

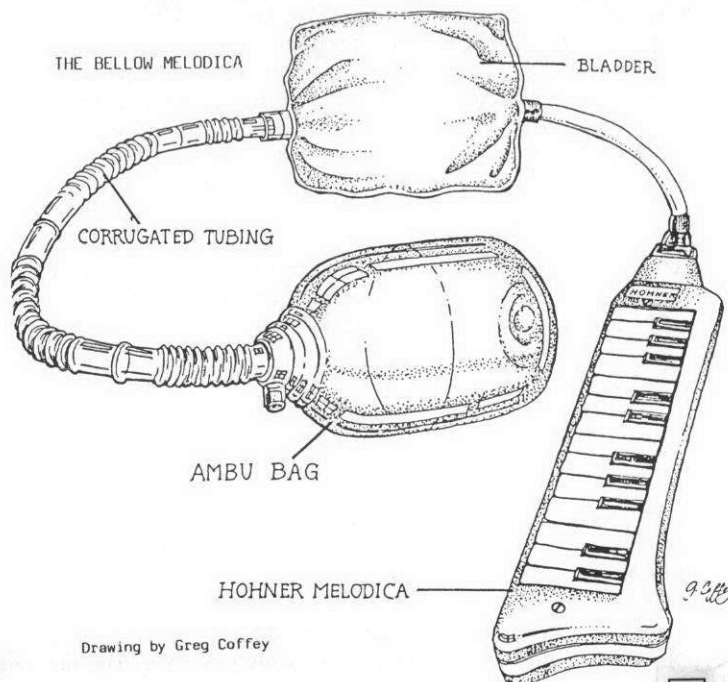
To further add to the possibilities of this name game ... when I first unveiled the instrument to my cohorts John Brennan and Gregg Coffey, they thought I said "Elbow Melodica." Which, considering the manner of playing, seems only natural. Moreover, the word **uilleann** (as in uilleann pipes) translates to the word "elbow."

QUESTION: What do uilleann pipes have to do with it?

ANSWER: The pipes were the initial inspiration for the Bellow Melodica.

I had read about and seen diagrams of bellows-blown bagpipes, but it wasn't until I saw the group **Skye** in performance that I had an opportunity to see them in action.

I watched Skye's Frank Edgely play both mouth-blown (Highland) and bellows-blown (Northumbrian) pipes that day. After their set, I plied Mr.



Drawing by Greg Coffey



Edgely with questions about the bellows arrangement. Unaware that I possessed warped sensibilities as well as a humble melodica back home, Frank instructed me to first obtain a practice chanter pipe and to learn fingerings.

In spite of his sound advice, I resolved at that point to keep my eyes open for a stray fireplace bellows that could be adapted for use with my melodica. I had that in mind when I came across a discarded "ambu bag" at the hospital where I work.

("Ambu" derives from "ambulatory", although it's pronounced to rhyme with "bamboo". Ambu bags are used to resuscitate non-breathing individuals, and they hold a volume of air which is equivalent, I presume, to that of an average adult human ... i.e., a lungful.)

To make this long story a little longer ... I adapted the ambu bag (with its two one-way valves) to fill up an air reservoir bladder which, when squeezed, provides a continuous jet of air for the melodica.

By placing the ambu bag under the right arm, and the reservoir bladder under the left arm, the player can then pump the bag to inflate the bladder. As the air is squeezed out of the bladder and into the melodica, it is simultaneously replenished by more pumping of the bag -- a process virtually identical to that used with uilleann (and other bellows blown) pipes. However, instead of using the air flow to vibrate the double reeds of the chanter and drone pipes, it is used to vibrate the free reeds of the melodica.

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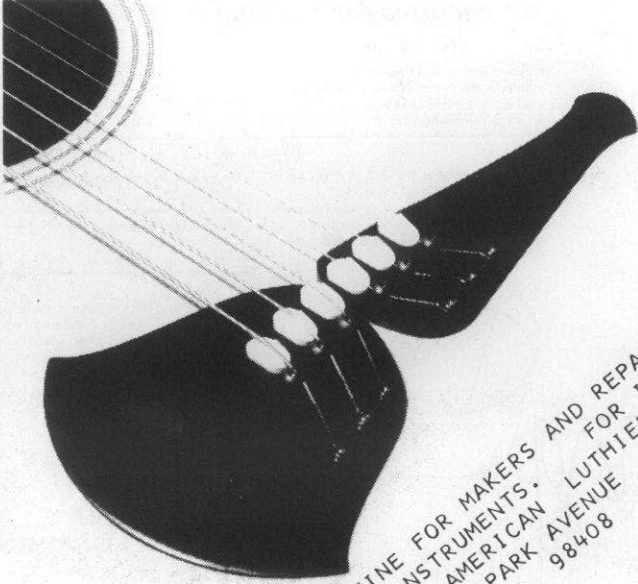
**1/1**: The Quarterly Journal of the Just Intonation Network, David B. Doty, editor. Serves composers, musicians, instrument designers and theorists working with tunings in Just Intonation. One year membership includes subscription. Individual, \$15 US, \$17.50 foreign; institution \$25. 535 Stevenson St., San Francisco CA 94103. (415) 864-8123.

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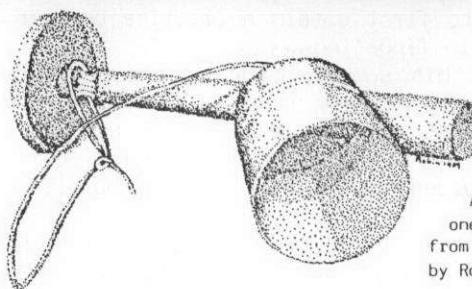
## HOOKED ON MAKING MUSICAL INSTRUMENTS

By Lindo Francis and  
Allan Trussell-Cullen

Published in 1989 by Longman Paul Limited. Paperback, 75 pages including photographs and line drawings. Available from I.C. Books, 5 Paulange Place, Pakuranga, Auckland, New Zealand. Price U.S. \$14.75 plus \$5 postage. An accompanying cassette tape is available separately from Lindo Francis, 28 Grande Ave., Mt. Albert, Auckland, New Zealand, for \$9 U.S., postage included.

**Hooked on Musical Instruments** is an instrument making book written for teachers by teachers of teachers. Authors Lindo Francis and Allan Trussell-Cullen are professors at Auckland College of Education in Auckland, New Zealand. Most of the book is devoted to instrument plans and ideas -- about 50 all told -- simple enough to be made and played by children or teenagers. Along with the plans are sections entitled "Suggestions for Teachers," which suggest activities related to the instruments, propose peripheral topics for exploration, and seek to tie instrument making and playing activities in with other parts of the curriculum. These things are preceded by an introduction delivered in the first person by none other than Ludwig van Beethoven, who turns out to be a very open-minded sort of fellow when it comes to musical expression. His monologue is an invitation to a more participatory approach to music making for us habitants of the twentieth century, concluding provocatively with, "So what do you say, folks?"

In **Hooked on Musical Instruments** the authors have created something which can be used by elementary or secondary school teachers with no special musical background, and, for that matter, by children themselves as well. The book is simple and direct in the text; catchy, clear and attractive in its visual presentation; and accessible and friendly throughout. And this is appropriate, because Francis and Trussell-Cullen invite teachers to make the contents of the book as directly available to students as possible, suggesting that they photocopy pages of their choosing, and pass them out to students or enlarge them for all to see. Permission to photocopy is ex-



A Whirly Pot --  
one of the designs  
from the book, rendered  
by Robin Goodfellow.

licitly granted by the publisher in a printed note at the bottom of all pages with instrument plans.

Many of the instrument ideas appearing here will be familiar to people who have worked before in the area of children's instrument making. Several more come from Lindo Francis' own explorations, and will be new to readers. There are sections devoted to Drums, Gongs, Bells, Rhythm (a catch-all including various sorts of friction, wind and percussion instruments and shakers), The Bucket Brigade (things you can do with a plastic bucket -- several clever and enjoyable ideas here), Tuned Percussion, and a Playground Orchestra.

A couple of sample instruments from the book:

The canophone (see the instructions page reproduced at right) is a tuned water chime set. It uses suspended beer cans holding varying amounts of water, struck on the rim with wooden beaters to produce a pretty combination of fast-decaying chime sound and lingering wobbles and echoes.

The bucket guitar (below) is a tension-controlled chordophone. It can be made in minutes from a plastic bucket and three guitar strings, with no tools required but a hammer and a nail to punch holes in the bottom. The strings run from

### Instructions for making a bucket guitar

#### You will need

- Plastic bucket with handle.
- Three guitar strings of different thicknesses  
— eg, B, G, and D strings.
- Drill or hammer and nail.

#### What to do

- 1 Make three holes about 5 or 6 cm apart across the bottom of the bucket.
- 2 Thread a guitar string up through each hole, so that the ball on the end of the string holds fast underneath the bucket. If there
- 3 is no ball end, tie on a button or just tie a large knot.
- 3 Hold the handle level with the rim of the bucket and tie each guitar string firmly to it.



That's all! Your bucket guitar is ready to play. With one hand, hold the handle so the strings are tight, and with the other, hold the bucket firmly against you. As you pluck the strings, pull on the handle and you will be able to change the note. Now you are ready to practise your serenade...

A  
page  
from  
**Hooked  
on  
Making  
Musical  
Instruments**



Cartoon by Fraser Williamson





anchor points in the bottom of the bucket up to where they are tied on the bucket handle. Pulling the handle to one side tautens the strings against the bucket's rim; pulling it more firmly increases the tension and raises the pitch. It's a clever use of the bucket's "natural" configuration, and accessible even to small children.

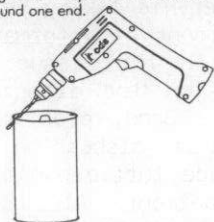
### Instructions for making a canophone

#### You will need

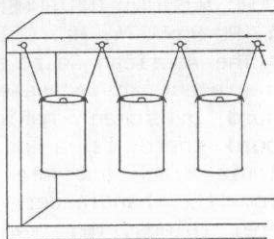
- Two 20 cm lengths of 2 cm diameter dowel.
- 6 drink cans (preferably not aluminium).
- 2.4 metres of nylon fishing line.
- Drill.
- Timber for wooden frame.

#### What to do

- 1 First, make your canophone drumsticks. Cut two lengths of dowel about 20 cm long and wrap some adhesive tape around one end.



- 2 Drill two holes in the cans as shown in the diagram.
- 3 Make the wooden frame as shown in the diagram, or for a temporary canophone, use a piece of wood placed between two desks.
- 4 Cut the nylon fishing line into 40 cm lengths and thread and tie them through the holes.



- 5 Hammer nails into the frame from which to hang the cans. There should be a gap of about 5 cm between the cans.
- 6 Add a little water to each can, starting with about a dessertspoon full.

You play your canophone by tapping the cans on the top of the rim (not the sides) with the tape covered end of the drumstick. Experiment with the water until the cans make interesting and contrasting notes. Try different rhythm patterns. Make up some melodies of your own. The authentic oriental sound makes this instrument ideal for providing background to plays and stories about the East.

Another page  
from the book

The cassette tape that accompanies **Hooked on Musical Instruments** is a guided tour through the sounds of the instruments described in the book, narrated by Lindo Francis. Its fidelity is not the best, but the tape serves well to give some sense of what the instruments can do. Clarity of reproduction aside, many of the sounds are wonderful, especially some of the friction instruments, the bucket bass and its brother the vibrabass, and the ensemble of tuned claves.

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PICTURE NOISES FROM THE GLOBAL SWAMP -- sonic documentation from the Madison intermedia Festival of the Swamps. Saxophone pyrotechnics, sound poetry, primal ranting, tense and precise improvisation, complex drumming. \$5 ppd. from Colin Hinz, 349 West St. N., Apt. #3, Orillia, Ontario, Canada, L3V 5E1. "Successful beyond documentation"-- Photostatic Magazine.

THE ONLY BOOK IN SAWING: **Scratch My Back: A Pictorial History of the Musical Saw and How to Play It**, by Jim Leonard and Janet Graebner. Features profiles of sawyers world-wide in 124 pages of fascinating information. Includes over 100 photos and illustrations, index and bibliography. U.S. Dollars \$19.95, \$3 shipping/handling (in CA add 6% tax). For information, contact Janet E. Graebner, Kaleidoscope Press, 1601 West MacArthur, #12F, Santa Ana, CA 92704.

"SINGING GLASSES: The Glass Harp: Liselotte Behrendt-Willach"; Quality cassette of classical and folk tunes by Europe's leading performer on glasses ground to pitch. \$8.50; \$1.50 S&H: Sampler Records, PO Box 19270, Rochester, NY 14619. 800-537-2755, Visa, Mastercard. Free catalog.

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EMI BACK ISSUES: Back issues of **Experimental Musical Instruments** numbered Volume V #1 and later are individually available for \$3.50 apiece. Earlier issues available in volume sets of 6 issues each, photocopied and bound: Volumes I through IV, \$14 per volume. Order from EMI, PO Box 784, Nicasio, CA 94946, or write for complete listing. Corresponding cassette tapes also available for each volume; see information below.

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JUST INTONATION CALCULATOR by Robert Rich. Composer's tool for JI. Internal sound for tuning reference; shows modulations; reduces fractions; converts between ratios, cents, DX711/TX81Z units; MIDI tuning dumps. Requires Macintosh with Hypercard -- only \$10.00. Soundscape Productions, Box 8891, Stanford, CA 94309.

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## RECENT ARTICLES IN OTHER PERIODICALS

The following is a selected list of recent articles from other publications of potential interest to readers of **Experimental Musical Instruments**.

GARLAND MAKES GOURD DULCIMERS LIKE HIS GRANDFATHER by John Bryant in the **Elizabethton Star**, August 6, 1989 (Elizabethton, Tennessee).

A report, with photographs, on instruments by T.N. Garland, who has made over 170 fretted dulcimers with gourd resonators based upon a design he learned from his grandfather.

THE STATE OF WILDERNESS SOUND by Jonathan Storm, in **Nature Sounds Society Newsletter**, Summer 1989 (Oakland Museum, Natural Sciences Division, 1000 Oak St., Oakland, CA 94607).

A report on the effect of air traffic on the general sound environment, with specific reference to the incursion of airplane noise even in otherwise pristine areas of the U.S. Includes proposals for responding to the problem.

THE BASICS OF PLASTICS by Susan Obermeyer in **TechniCom** Vol. 13 #4, July-August 1989 (PO Box 51, Normal, IL 61761).

Concise and brief basics on safety, forming, machining and joining for the different families of plastics, written for band instrument repair people.

HARPMAKER'S NOTEBOOK #11 -- REAL STRINGS, PART 2 by Mark Emery Bolles in **Folk Harp Journal** #66, Fall 1989 (4718 Maychelle Dr., Anaheim, CA 92807-3040).

The second in Bolles' valuable series on practical string acoustics. This installment begins with some comments about math phobia, and then picks up where Part 1 left off in presenting formulas relating the several factors affecting string scaling.

TIMBRE, PARTS 2 and 3, by David Courtney, in the Newsletter for Shastriya Sangeet, August and September 1989 (Box 270685, Houston, TX 77277).

Brief looks at harmonic structure and psycho-acoustic considerations as components of timbre.

**American Lutherie** #19, Fall 1989 (8222 South Park Ave., Tacoma, WA 98408) has informative articles on historical lute construction, mandolin orchestras and baroque guitar restoration. In addition it contains two short pieces from Francis Kosheleff on some of his unorthodox plucked string forms: THREE-LEGGED BRIDGE discusses an approach to bridge design for plucked strings which uses three or four feet contacting the sound table at points selected for their relationships to bass and treble bracing patterns on the inside of the board. THE FERAL BALALAIKA is a humor piece about a degenerate form of balalaika allegedly found living in the wild in California's Santa Cruz Mountains. Included is a photo of the thing -- a big, oddly shaped hollow log with 12 strings, unruly looking but apparently playable.

'IMPOSSIBLE' FORM OF MATTER TAKES SPOTLIGHT IN STUDY OF SOLIDS by Malcolm W. Browne, in the Science Times section of the **New York Times**, Sept. 5, 1989.

This article discusses a category of crystal-line structures called quasicrystals, which may have important applications if they can indeed be produced. One of the most useful models for studying the three-dimensional lattices of such structures has involved vibration transmission patterns of linked networks of tuning forks.

GOURD MUSICAL INSTRUMENTS, in **The Gourd** Volume 19 #4 (PO Box 274, Mt. Gilead, OH 43338).

The American Gourd Society is making an effort to present an increased amount of information on gourd instrument making. In this issue of **The Gourd** there is a column on the irrepressible Minnie Black and her Gourd Band, plus a letter from the bandleader herself discussing, among other things, her newly-made turtle banjo, which she uses in song accompaniment. Also in this issue are an INTRODUCTION TO GOURD MUSIC by Terrence Laine, with photographs of his guiros and shekeres, and a piece on PREPARING DRIED GOURDS FOR MUSICAL INSTRUMENT MAKING according to Tony Pizzo. The photographs throughout -- including other forms of gourd craft as well as musical instruments -- are irresistible.

**The Music Trades** Volume 137 #9, October 1989 (80 West St., PO Box 432, Englewood, NJ 07631) focuses on "The Vibrant U.S. Guitar Market," and includes three articles which take us, in words and photographs, onto the factory floor for some of the big guitar manufacturers: Guild, Peavey, and a Paul Reed Smith.

**Ear** Volume 14 #6, September 1989 (131 Varick St. Room 905, New York, NY 10013) focuses on ensembles of like instruments. Among the articles is an interview with Glenn Branca, who composes for groups of instruments derived conceptually from electric guitars, but which in their final incarnation are quite different, and uniquely suited to Branca's purposes. There are also features on ukulele orchestras; Wendy Chambers' unlikely ensembles of timpani, harps or grand pianos; and other all-in-the-family consorts.

**Ear** Volume 14 #7, October 1989 (address above) contains these articles:

TRIMPIN: ELECTROACOUSTIC WIZARD, by Iris Brooks, is an interview with Trimpin, who makes computer-controlled mechanically operated instruments, often taking junk or scrap materials as acoustic sound sources.

SOUND/WATCH, in the "Festivals" section, is a report on the Sound/Watch festival in New Zealand. Among the diverse happenings were several involving new instruments or unorthodox approaches to traditional instruments.